Enhancing Battery Recharge Performance through an Intelligent MPPT for Photovoltaic Solar Panels

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Abstract. Fuzzy Logic MPPT (Maximum Power Point Tracking) is one of the most powerful boosting techniques for photovoltaic panels. One of the main challenges of a Photovoltaic Device enhanced with a fuzzy circuit control is the fact that it requires the photovoltaic panels to work at their maximum power point while having a high performance. In this study, an intelligent MPPT system is proposed that aims to enhance the performance of the recharge factor as well as decrease the resource spent to complete the task. To accomplish this, a fuzzy logic technique is proposed that uses a three-step charging factor. MATLAB SIMULINK is used to simulate and validate the results in a numerical experiment. Ultimately the results indicate that a three-step charge enhances the recharge factor and decreases the cost whilst improving the performance.

Keywords: PI-Fuzzy Control, Charge Control, PV Panels, MPPT, Intelligent Systems.

1 Introduction

The rise in energy consumption around the world, as well as the fact that fossil fuels are slowly running out, has led to the rise of clean renewable energies. Solar energy is one of the top contenders for the renewable energy category, especially in Middle Eastern countries that have an inordinate amount of sunlight exposure. One of the most popular solar-sourced energy production is via photovoltaic solar panels [1]. Although this technique has several benefits associated with renewables, it does also have its drawbacks. First, the daily energy conversion rate for solar panels is between 9% to 17%, which is considered very low. This is further exasperated by the fact that factors such as temperature and irradiance play a major role in the energy conversion rate, making the process even more unreliable than it already is [2]. The maximum power point output of the photovoltaic system is heavily dependent on the climate, the maximum power input, and the voltage associated with the photovoltaic panels. The climate itself is not controllable, albeit predictable if the panels were to be located in places that have a high percentage of sun exposure. However, besides the issue of the climate, other attributes such as the system efficiency can directly impact the output of the Photovoltaic system. To cut costs of a PV system, while also maximizing its efficiency, the system would need to operate at its peak power point [3]. There are several existing algorithms in the literature that are based on MPPT, such as Perturb & Observe, Inc. Conductance [4], and Fuzzy Logic. Each MPPT algorithm has its own set of pros and cons. While some are efficient in their processing, they are at the same time very expensive to execute. PV power systems include DC-DC converters, buck-type DC-to-to-DC converters a duality. MPPT algorithms extract voltage and current from the polarity of photovoltaic panels and monitor the service cycle of PWM (Pulse width Modulation) applied to the switch (MOSFET, IGBT, and so on) of DC-DC converters to

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regulate the converter's voltage and current. However, the Fuzzy Logic Control method is considered very reactive depending on the environment they are set up in. Additionally, the FLC does not require device parameters to operate. Current and voltage are continuously changing after the boost converter is initiated due to the changing environmental conditions and the characteristics of the circuit elements [5]. To charge the battery quickly and efficiently, a constant current is required, as well as a sufficient voltage while charging. [6]. However, charging the battery quickly may affect the lifecycle of the batter adversely.

The charge controller loads the battery in stages to ensure that it is fully charged without causing damage to the battery due to unnecessary charge gassing and overheating [7]. Numerous previous works of literature cover the study of various MPPT algorithms, their modelling, and implementation in Simulink [8]. These publications, however, do not evaluate the MPPT tracking performance in terms of tracking time or tracking quality. Additionally, there is no discussion about how to combine this MPPT with a battery charge controller.

Tauhid Latif and co-Furs in 2014 [9] studied a SEPIC/PI process for enhancing control voltage, which was compared to a device that only used a buck converter and a battery with Incremental conductance. The proposed system is different, and the boost converter only has one circuit, so the losses are lower with the FLC MPPT method; because the system isn't being analysed, the number of components is significantly fewer, and the design is simpler. But it can also double as a boost converter or as well as a buck converter.

Hari Shankar Suresh and colleagues [10] investigated a device in 2014 that used Perturb & Observe MPPT methods and a buck-boost converter to regulate the current and voltage of a photovoltaic panel, as well as an open circuit method to monitor the battery charge. With the proposed device, Pert & Observe oscillates about maximum power point, and as a result, this causes power loss, The proposed system is schematized in **Error! Reference source not found.**.

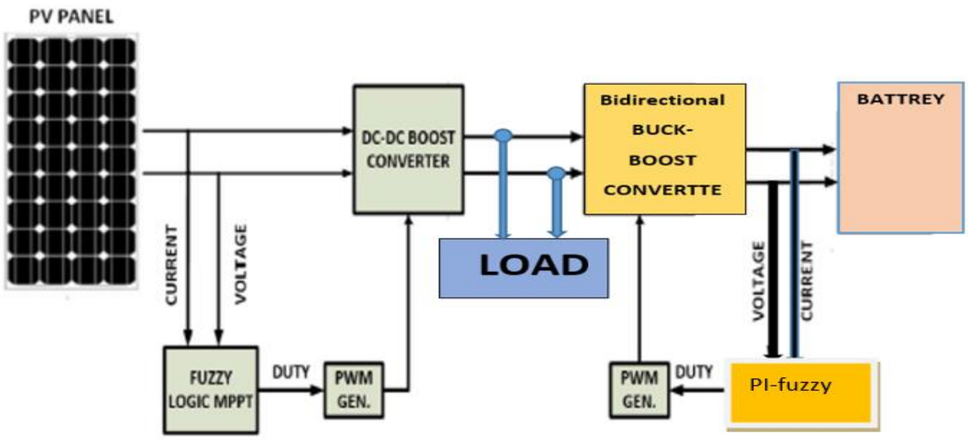

Fig 1. PV system MPPT algorithm and PI –fuzzy control charge circuit.

2 Methodology

Error! Reference source not found. demonstrates the basis for the stand-alone photovoltaic power generation system's power converter system. This framework integrates a

maximum power point monitoring controller with a bidirectional buck-boost converter with charge and discharge control. The battery charge and discharge controllers use a bidirectional buck-boost converter that possesses both buck and boost converter characteristics [11].
In the end, the output of energy conversion has been significantly increased. Additionally, this converter acts as a battery energy storage device within the system structure but also enables an auxiliary power supply at the load terminal. The power supply can be regulated and operated by implementing the device characteristics described previously.
The Fuzzy Logic MPPT algorithm is more challenging to implement but offers better PowerPoint locating capability. You are not required to understand the system's model; all inputs to an MPPT controller must be either error or change. It includes the following equations that illuminate the principles of E and EC [12].

$$E(k) = \frac{\Delta P}{\Delta I} = \frac{P(k) - P(k-1)}{V(k) - V(k-1)} \tag{1}$$

$$EC(k) = E(k) - E(k-1) \tag{2}$$

In equation (1), P stands for power, while V is the voltage associated with the photovoltaic panel. The logic of the equation dictates that to calculate the principles of E, which takes the values of the previous power and voltage, to get the absolute values for them. If the equation is positive, meaning and the current power and voltage are higher than the previous power and voltage, then this means that based on the Fuzzy Logic MPPT, the voltage should be increased. This process is illustrated in Fig 2. The voltage is increased, so long as the relationship remains positive. The relationship is set up in such a way that a positive change in power, would require a negative change in voltage to keep the point at its maximum value possible [5].

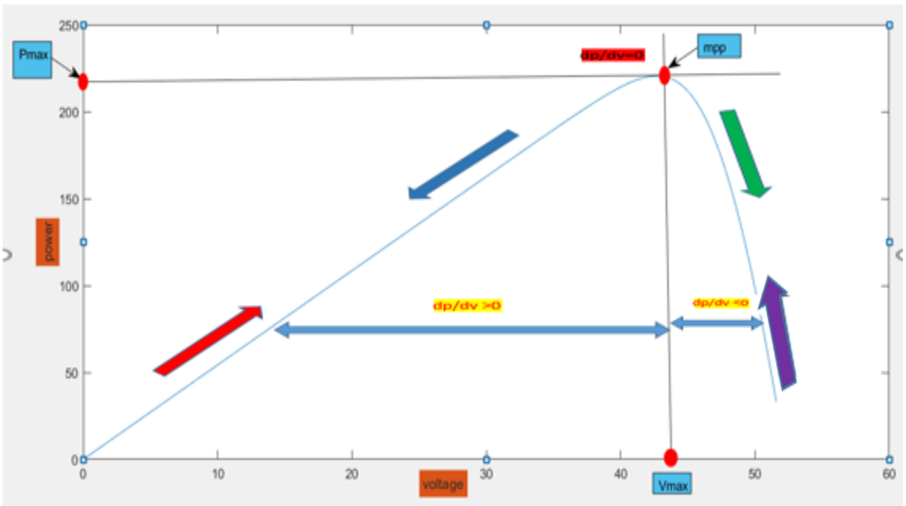

Fig 2. Voltage Power Relationship on the FLC Algorithm for the PV System.

This figure establishes what is required for the system to do to reach its MPP. Thus, establishing the logic behind the simulation as well as the corrective course for the photovoltaic panels.

3 Proposed Converter and Controller

This research proposed a bidirectional buck-boost converter as illustrated in Fig 3 for managing the storage and supply of energy across photovoltaic and battery systems. Due to the bidirectional nature of the circuit layout of a bidirectional converter, two operating modes can be selected depending on which way of the power flow boost and buck types. The boost mode also knowns as the discharging mode, the converter is either open or closed depending on the state of the switch-mode power supply (SMPS). In the buck mode also knowns as the charging mode, the proposed power flows from the DC bus to the battery bank to charge the battery [13].

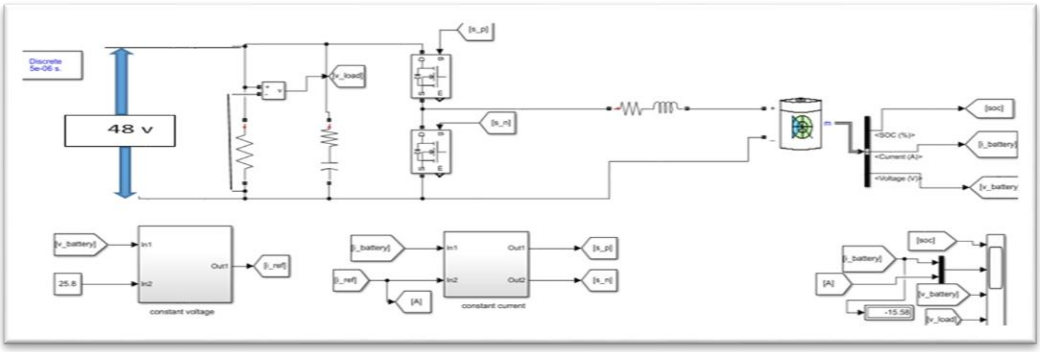

Fig 3. Proposed Bidirectional Buck-Boost Converter.

Regarding the proposed battery charge controller, it was developed using a lead-acid battery with three-state charging methods of constant current charging, constant voltage charging, and float charging. The flowchart illustrated in Fig 4 elaborates on the inner workings of the proposed three-stage battery controller. The controller measures the state of charge (SoC), if the value is at full capacity, meaning 100%, then the system is sent to float charging where the batter is aimed at maintaining 100%. However, if the SOC is lower than 80% then two conditions apply, either bulk charging or absorption charging. The bulk-charging scenario works when SOC is lower than 80%, thus the battery is charged at its rated capacity based on the MPPT. The absorption charging works when the SOC is valued at above 80%. In this scenario the MPPT is disabled, and the battery is charged at a constant voltage. The float charging ensures that the SOC does not go over 100% and thus prevents any excessive uncontrolled charge.

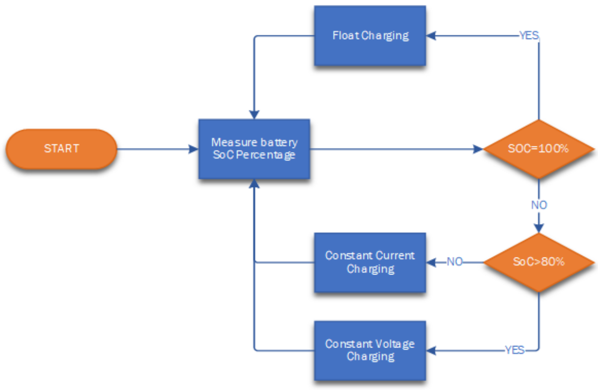

Fig 4. Three-stage lead-acid battery charge controlled flowchart.

4 Results of the Simulation

Applying both the MPPT, with the FLC as well as the three-stage charging lead-acid battery resulted in improved performance. The results are illustrated in Figure 5. It is indicated that when the lead-acid battery type is used in conjunction with using a 24 volt and 100 AH capacity with a 99.7% charging using the three-stage charging. During the one minute that the simulation was running, there was an indication that the photovoltaic array produced 1066 W of power.

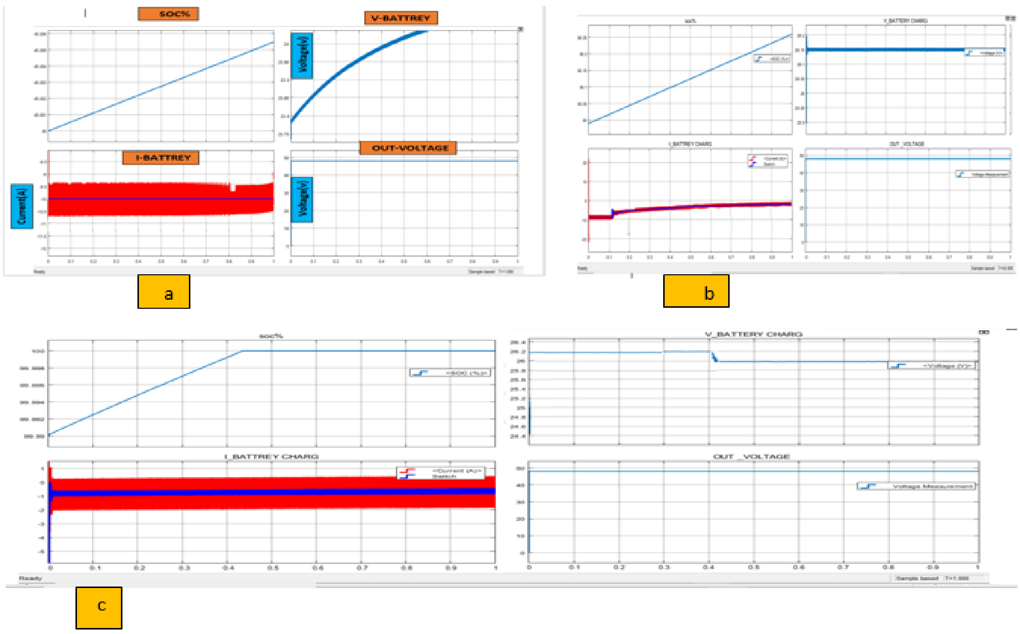

Fig 5. Scheming the charge of a lead-acid battery in three states of (a) constant current, (b) constant voltage, and (c) float charging.

5 Conclusion

In this study, a photovoltaic control circuit was proposed based on a combination of Fuzzy Logic and MPPT. Using Simulink to numerically simulate and validate the results on a photovoltaic system modelling circuit. This system was made using a module with simulations that included the MPPT FLC algorithm, the boost converter, and the three-stage charge controller. The results of the simulation indicate that the MPPT battery charger is capable of charging a 24 V lead-acid battery, using a three-stage charging strategy. This system tracks the maximum power produced by a 1.2 kW PV array source. The overall efficiency of the system reached 99.3%, which is on par with currently commercially sized high-end PVs.

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